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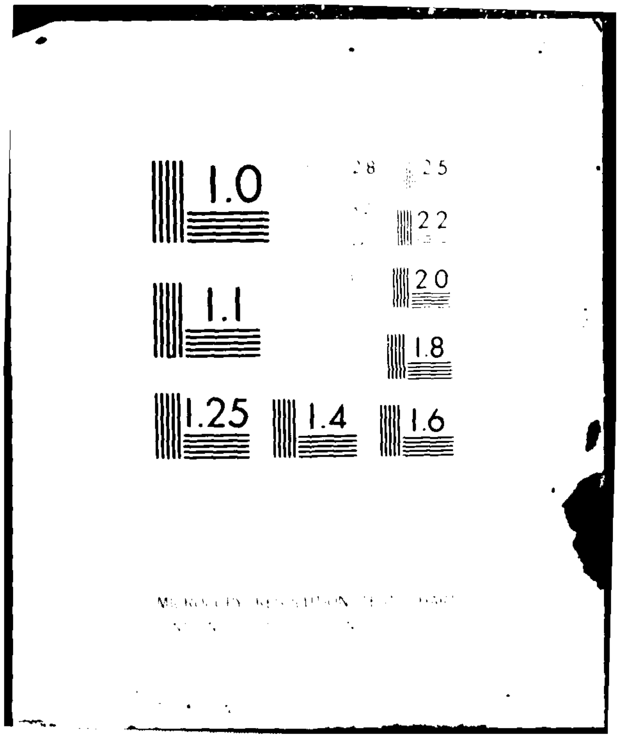
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# Composition and Structure Measurements in an Ionospheric Barium Cloud

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G. FEDERICO
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P. BENCH

23 December 1981

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Chief Scientist

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)


A 48 kg barium payload was launched from Eglin Air Force Base, Florida on 12 December 1980 at 2311 GMT and detonated at 183.7 km. At 2342:50.25 GMT, a second rocket, instrumented with an ion mass spectrometer and pulsed plasma probes, was fired to traverse the barium cloud. Composition, ion density, and structure measurements were acquired up to 241.2 km in both the natural and disturbed ionosphere. The rocket penetrated the barium cloud between 147 and 184 km. In addition to the $Ba^+$, $Ba^{++}$ produced by H Lyman α ionization, and $Ca^+$, an impurity in the barium, were


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detected in the cloud. A peak barium ion concentration of about $6 \times 10^6$ ions $cm^{-3}$ was measured at 161 km where the ionospheric $NO^+$ and $O_2^+$ ions were essentially eliminated by large recombinative loss. The bottom side of the barium cloud had a relatively smooth structure while the top side showed significant density fluctuations. The first experimental evidence of a theoretically predicted E region "image cloud" was found in the form of an enhanced $NO^+$ layer just below the barium cloud. Unexplained wave-like density variations in $O^+$, $NO^+$, and $O_2^+$ also were seen above the barium cloud to 195 km. A quantitative estimate of the outgassing water vapor concentrations near the payload's surface was made using the fast charge transfer rate coefficient for $O^+ + H_2O \rightarrow H_2O^+ + O$ that created the observed water vapor ions. It was determined that the measured $H_2O^+$ ions were produced within 3 to 4 cm of the sampling plate's surface and that the average $H_2O$ pressure over this distance was constant on ascent at $8 \times 10^{-6}$ Torr within a factor of two.

# Preface

Funding for the ion mass spectrometer measurements was provided mostly by the Air Force Office of Scientific Research under Task 2310G3. The Defense Nuclear Agency supplied the rocket integration and launch costs. We thank Dr. E. P. Szuszczewicz for his advocacy and cooperation in conducting this experiment. Finally, we acknowledge the Sandia National Laboratories for their excellent rocket and payload integration support.

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## Illustrations



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# Composition and Structure Measurements in an Ionospheric Barium Cloud

## 1. INTRODUCTION

The only in situ measurements of atmospheric barium releases are those of the electron density structure performed by Baker and Ulwick[1] as part of the Defense Nuclear Agency's (DNA) STRESS program. Kelley et al[2] analyzed the STRESS results and demonstrated that the late-time barium striations agree with non-linear Rayleigh-Taylor instability development; the same mechanism believed to create equatorial Spread F.

This report describes the first measurements of the ion composition and structure made in a barium cloud. The effort was part of the DNA PLACES (Position Location and Communication Effects Simulations) program. The barium/probe rocket pair and associated measurements were further designated as event "JAN." The barium payload was launched from the Eglin Air Force Base, Florida, Test Range on 12 December 1980 at 2311 GMT releasing 48 kg of barium at 183.7 km. At 2342:50.25 GMT a Terrier Tomahawk rocket payload was launched containing an

(Received for publication 21 December 1981)

1. Baker, K.D., and Ulwick, J.C. (1978) Measurements of electron density structure in striated barium clouds, Geophys. Res. Lett. 5:723.
2. Kelley, M.C., Baker, K.D., and Ulwick, J.C. (1979) Late time barium cloud striations and their possible relationship to equatorial Spread-F, J. Geophys. Res. 84:1898.

ion mass spectrometer and pulsed plasma probes targeted to penetrate the barium cloud. In this report we present the instrumentation, measurement technique, the data, and some implications of the measurements from the ion mass spectrometer.

## 2. INSTRUMENTATION AND MEASUREMENT PROGRAM

The mass spectrometer was mounted at the forward end of the payload along the vehicle's axis. Figure 1 shows the payload configuration and flight functions. Trajectory parameters are given in Table 1. The spectrometer was activated following nose cone release that simultaneously removed the instrument's vacuum cap. The payload included an attitude control system (ACS) that aligned the payload's axis with the magnetic field to minimize perturbations on the pulsed plasma probes. The ACS maintained the payload to within ± 5° of the magnetic field on ascent and most of descent. Also, the roll rate was held to less than ± 0.6° $sec^{-1}$. Nevertheless, the angle of attack between the velocity vector and the spectrometer axis was still favorable since the rocket was launched essentially along the magnetic field. The attack angle was less than 25° to about 200 km on upleg, increased above this altitude, and became large on descent.

Table 1. Event JAN Probe Payload Trajectory Tabulation Excerpted From a Single Station Radar Solution Prior to Smoothing

| Time After Lift-Off (sec) | GMT | Altitude (km) | Range (km) | Latitude | Longitude | Velocity km/sec |
|---|---|---|---|---|---|---|
| 50.55 | 2343:40.8 | 68.83 | 76.64 | 30.0855 | 86.8274 | 2.05 |
| 100.55 | 2344:30.8 | 146.05 | 167.31 | 29.6615 | 86.8717 | 1.65 |
| 150.55 | 2345:20.8 | 200.63 | 238.71 | 29.2428 | 86.9211 | 1.29 |
| 200.55 | 2346:10.8 | 232.11 | 291.46 | 28.8321 | 86.9735 | 1.04 |
| 245.8 | 2346:56.1 | 241.22 | 325.28 | 28.464 | 87.0227 | 0.94 |
| 250.55 | 2347:0.8 | 241.13 | 328.09 | 28.4265 | 87.0277 | 0.94 |
| 300.55 | 2347:50.8 | 227.91 | 352.19 | 28.0193 | 87.0830 | 1.05 |
| 350.55 | 2348:40.8 | 198.22 | 368.53 | 27.6732 | 87.3808 | 1.31 |
| 400.55 | 2349:30.8 | 133.24 | 384.03 | 27.1886 | 87.1935 | 1.68 |
| 448.55 | 2350:18.8 | 54.29 | 407.36 | 26.7800 | 87.2469 | 2.31 |

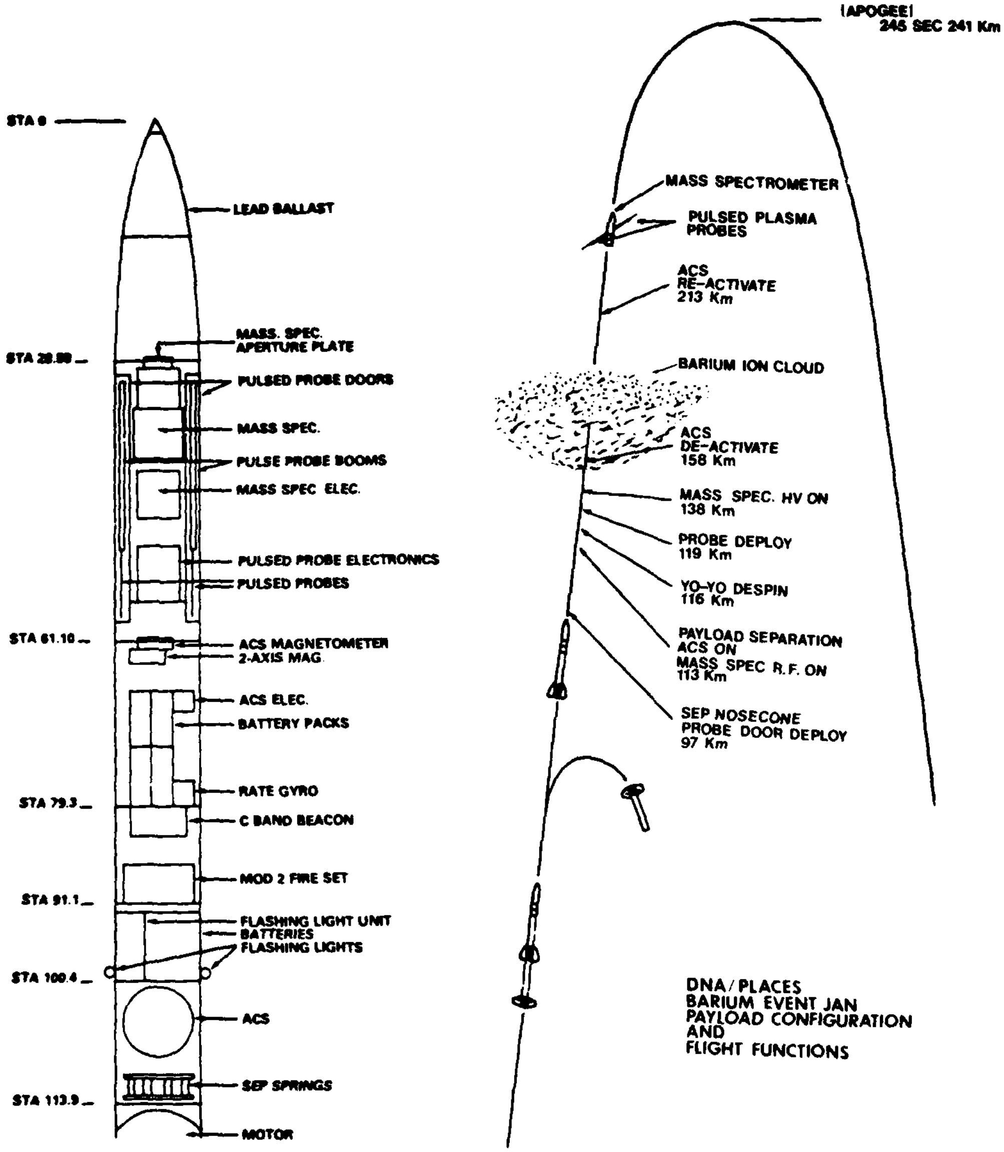


*Figure 1. Payload Instrumentation and Flight Events*

Figure 2 shows a schematic of the quadrupole ion mass spectrometer. The two significant data outputs were the total positive ion current collected on the aperture

plate for ionospheric structure measurements and the mass spectra output for species composition. The spectrometer measurement program is presented in Figure 3. Sixty-four masses were sampled digitally for 10 msec each, yielding a total program period of 0.64 sec. Mass number repetitions provided measurements with high spatial resolution. Above 145 km, the aperture plate output had a 1 to 1.5 m altitude resolution (varying with vehicle velocity) while the barium and oxygen ion measurements had a resolution of 50 to 65 m. The species identifications for the associated mass numbers in Figure 3 are 14($N^+$), 16($O^+$), [contaminants from outgassing water vapor: 17($OH^+$), 18($H_2O^+$), and 19($H_3O^+$)], 23($Na^+$), 24($Mg^+$), 27($Al^+$), 28($Si^+$), 30($NO^+$), 32($O_2^+$), 40($Ca^+$), 56($Fe^+$), 69($Ba^{++}$), 136-138($Ba^+$). The remaining mass numbers were selected to establish background levels. The barium isotopes of 136 and 138 amu with relative abundances of 7.81% and 71.66%, respectively, were chosen to provide an added factor of about 9 in sensitivity in case 138 went off scale (exceeding $10^7$ ions $cm^{-3}$).

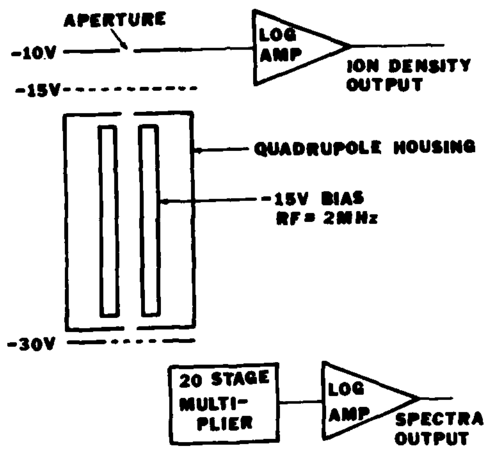


Figure 2. Schematic of the Quadrupole Ion Mass Spectrometer

## 3. RESULTS AND DISCUSSION

Composition measurements were acquired between 142 and 241.2 km on upleg and on downleg to 180 km, below which the large angle of attack caused signal drop-out. The ion species measured, included $O^+$, $NO^+$, $O_2^+$, $Ba^+$, $Ba^{++}$, $Ca^+$, and $H_2O^+$; all other species were below the set detection limit of about 40 ions $cm^{-3}$.

MASS PROGRAM

| SEQUENCE # | MASS # - AMU | | | | |
|---|---|---|---|---|---|
| 1. | 16 | 14 | 30 | 136 | 138 |
| 2. | 16 | 14 | 32 | 136 | 138 |
| 3. | 16 | 14 | 30 | 136 | 138 |
| 4. | 16 | 14 | 32 | 136 | 138 |
| 5. | 16 | 14 | 30 | 136 | 138 |
| 6. | 16 | 14 | 32 | 136 | 138 |
| 7. | 16 | 14 | 30 | 136 | 138 |
| 8. | 16 | 14 | 32 | 136 | 138 |
| 9. | 16 | 14 | 30 | 136 | 138 |
| 10. | 13 | 14 | 15 | 16 | 17 |
| 11. | 18 | 19 | 21 | 23 | 24 |
| 12. | 27 | 28 | 30 | 32 | 69 |
| 13. | 136 | 138 | 40 | 56 | |

SAMPLE RATE: 10 MS/AMU

PROGRAM TIME: 0.64 SECONDS

Figure 3. Spectrometer Program for the Measurement of Selected Ion Mass Numbers at High Spatial Resolution

The results are presented in terms of the measured species currents vs altitude. To obtain absolute density values to within ± 50% for all species below about 225 km, the following conversion factors may be applied: for $NO^+$, $O_2^+$, and $H_2O^+$, $1 \times 10^{12}$ ions $cm^{-3}$ $amp^{-1}$; for $O^+$, $8 \times 10^{11}$ ions $cm^{-3}$ $amp^{-1}$; and for $Ba^+$, $Ca^+$, and $Ba^{++}$; $1.3 \times 10^{12}$ ions $cm^{-3}$ $amp^{-1}$. The accuracy in the species densities can be improved somewhat by normalizing to the more precise electron concentrations from the pulsed plasma probes.[3]

Figure 4 shows the ascent measurements of $O^+$, $NO^+$, $O_2^+$, and $Ba^+$. It is seen that the barium cloud was entered at 147 km and exited at 184 km. The peak barium ion concentration (including all isotopes) was about $6 \times 10^6$ ions $cm^{-3}$ near 161 km. The underside structure of the barium cloud was relatively smooth; the small bite-out at 158 km was due to a nitrogen gas burst from the ACS nozzle. (The ACS was deactivated slightly above this altitude and reactivated at 213 km on upleg but no nozzle fire occurred until 178 km on descent.) In contrast, the topside of the barium cloud had significant density fluctuations. The $NO^+$ and $O_2^+$ ions were, as expected,

3. Szuszczewicz, E.P., Holmes, J.C., Swinney, M., and Lin, C.S. (1981) DNA/PLACES barium event JAN: Quick-look field report on in-situ probe measurements, NRL Memorandum Report No. 4476.

severely depressed in the barium plasma. It can easily be shown that the increased molecular ion loss rate by electron recombination would deplete the molecular ions to less than 40 ions $cm^{-3}$ in a matter of a few seconds in the vicinity of the barium peak concentration. On the other hand, the $O^+$ ions, which are atomic ions with an exceedingly small electron recombination rate, are essentially unaffected by the barium ion plasma except for some induced irregularity structure.

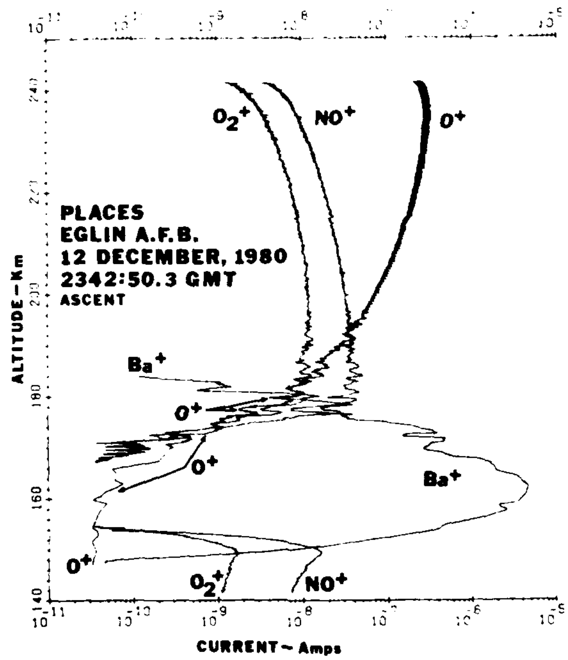


Figure 4. Ascent Measurements Showing the Penetration of the Barium Cloud and its Effects on the Normal Ambient Species $NO^+$, $O_2^+$, and $O^+$

If an unperturbed $NO^+$ profile is constructed in Figure 4 by extending the lower and upper altitude $NO^+$ profiles into the depletion, it is found that there is a definite enhancement in $NO^+$ of approximately 50% near 149 km, just below the barium cloud. The thickness of this enhanced layer is about 3 km. It is worth noting that this layer is not easily observed in the total ion density profile (see below aperture plate results) being smeared out by the sharply increasing barium ion density.

S. L. Ossakow, (Naval Research Laboratory, private communication, 1981) has suggested that the $NO^+$ bulge may represent the first experimental observation of an image cloud induced in the E region by electrostatic coupling with an F region barium cloud.[4,5] Interestingly, irregularities or density fluctuations in $O^+$, $NO^+$, and $O_2^+$ persist well above the barium cloud to about 195 km; whereas the ionospheric structure above and (as shown later) throughout descent is strikingly smooth. Further, above about 176 km, the density fluctuations in $NO^+$, $O_2^+$, and $O^+$ are similar. Currently, there is no explanation for the wave-like structure that extends into the F region; indeed, Lloyd and Haerendel[6] have noted that image cloud effects in the F region are negligible. Future modeling calculations are planned to determine the concentrations and extent of the E region image cloud. Also, attempts will be made to find the processes responsible for the higher altitude irregularities.

An expanded plot of the $Ba^+$ distribution also showing $Ca^+$ and $Ba^{++}$, is shown in Figure 5. The $Ba^{++}$ ion was expected to be present because the second ionization potential of $Ba^+$ is only 9.95 eV and H Lyman $\alpha$ radiation is sufficiently energetic to produce the doubly ionized species. Since the barium payload was launched near 5° solar depression angle, H Lyman $\alpha$ illuminated the release for several minutes before being completely attenuated. The only significant chemical loss process known for $Ba^{++}$ is $Ba^{+} \cdot NO \rightarrow NO^+ + Ba^{'}$. This type of reaction has been measured for $Ca^{++}$ and found to be very fast, but the analogous reaction with $Ba^{++}$ has not been measured and must be very slow to explain the persistence of $Ba^{++}$ about 20 min after the ionizing radiation is cut-off. Neither the photoionization cross section nor the atmospheric chemical loss processes for $Ba^{++}$ are currently known.

From the manufacturer's analysis, the barium material utilized had a purity of 99.57% with a 0.04% each of Ca, Al, Mg, and Sr, as well as other impurities (Peter Kirschner, Thiokol Chemical Corp., private communication, 1981). No magnesium or aluminum ions were detected above the threshold limit of about 40 ions $cm^{-3}$. Unfortunately, no strontium ion measurements were programmed. The ratio of the number of calcium atoms to barium atoms in the atmospheric release was therefore about $1.4 \times 10^{-3}$. The $Ca^+/Ba^+$ ionic ratio varied from about $2.5 \times 10^{-4}$ at low altitudes up to the barium peak and increased to about $10^{-3}$ at

4. Goldman, S. R., Ossakow, S. L., and Book, D. L. (1974) On the nonlinear motion of a small barium cloud in the ionosphere, J. Geophys. Res. 79:1471.
5. Scannapieco, A. J., Ossakow, S. L., Book, D. L., McDonald, B. E., and Goldman, S. R. (1974) Conductivity ratio effects on the drift and deformation of F region barium clouds coupled to the E region ionosphere, J. Geophys. Res. 79:2913.
6. Lloyd, K. H., and Haerendel, G. (1973) Numerical modeling of the drift and deformation of ionospheric plasma clouds and of their interaction with other layers of the ionosphere, J. Geophys. Res. 78:7389.

higher altitudes, with both ions reflecting similar structure. The increasing $Ca^+/Ba^+$ ratio with altitude does seem to be in agreement with the diffusion of barium and calcium ions according to their respective scale heights although this may be further complicated by the electromagnetic field- and wind-driven motions of these ions. While the barium ion cloud was optically observed to be moving in a northeasterly direction, the cloud center height was also seen to be falling at roughly 0.75 km $min^{-1}$ (W. Boquist, Technology International Corp., private communication, 1981). No further attempt will be made here to examine quantitatively the motions or ionospheric processes of these ions; however, this effort may be worthwhile in the future to investigate possible mass dependent effects in the formation of ionospheric instabilities.

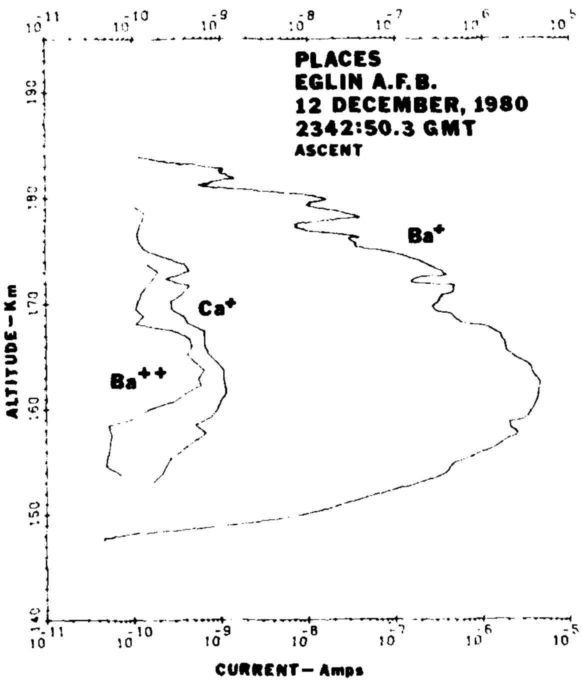


Figure 5. Distributions of Constituents From the Barium Release. Calcium is a typical impurity in barium

Plotted separately to reveal clearly the structure below 195 km are $NO^+$ (Figure 6), $O_2^+$ (Figure 7), and $O^+$ with $H_2O^+$ (Figure 8). The entire aperture plate current output is given in Figure 9, exhibiting measurements from 98 km to 241.2 km on ascent and to 80 km on descent. The plate current measurements are not as seriously affected by the large vehicle attack angles. Except for the depression near 178 km on descent caused by an ACS nitrogen jet fire, the ionospheric structure is exceedingly smooth outside the barium cloud. An expanded plot of the area of the barium cloud is shown in Figure 10. The aperture plate current and the pulsed probe profiles of Szuszczewicz et al[3] show a complete congruency in structure even to the tiniest density fluctuations.

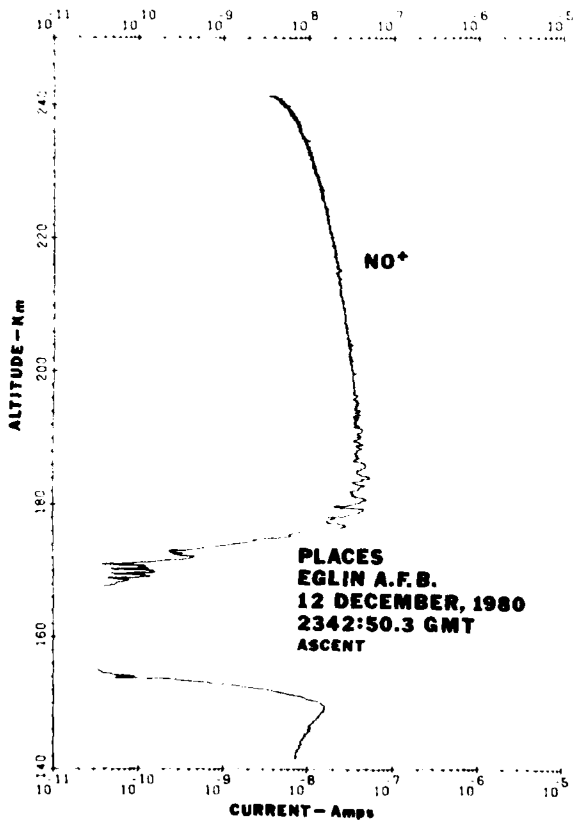


Figure 6. The $NO^+$ Profile Measured on Ascent

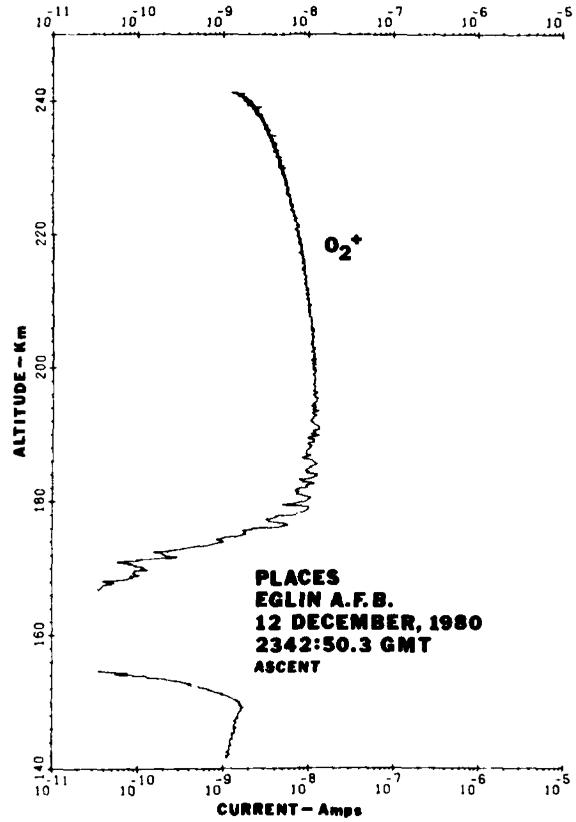


Figure 7. The $O_2^+$ Profile Measured on Ascent

Finally, we shall use the measured $H_2O^+$ concentrations to make a quantitative estimate of the outgassing water vapor concentrations near the payload surface. A quantitative measurement or determination of typical water vapor concentrations surrounding rocket vehicles has not been performed in the past and has long been needed to assess perturbations on a variety of rocket measurements. Rocket payloads are driven from atmospheric pressure to high vacuum in less than 2 min with total flight times of about 6 to 12 minutes. Since laboratory vacuum systems are known to outgas water vapor for long periods of time after initial pump-down, rocket surfaces will certainly have significant degassing rates over the entire flight. Further, experience has shown that the usual practice of purging payloads with dry nitrogen for several hours prior to launch does not drastically mitigate the degassing rates.

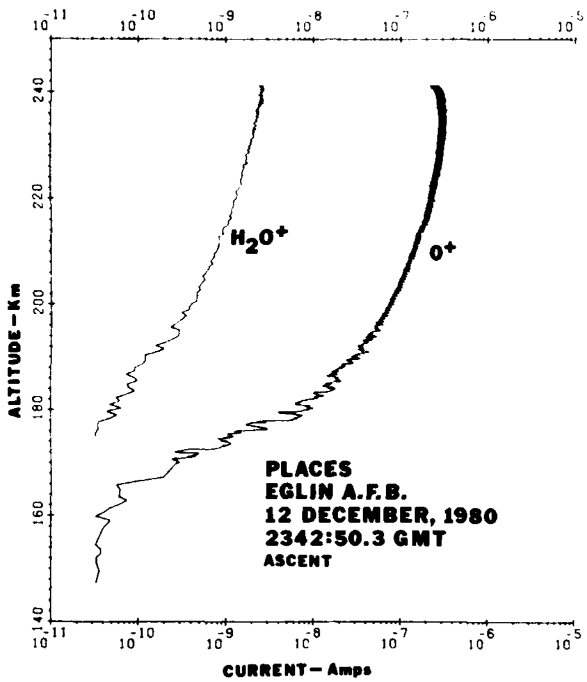


Figure 8. Ascent Measurements of $O^+$ and the Contaminant $H_2O^+$. Note the structure similarity and the constant $H_2O^+/O^+$ ratio

To calculate the water vapor concentrations we utilize the fast charge transfer reaction, $O^+ + H_2O \rightarrow H_2O^+ + O$, $k = 2.3 \times 10^{-9}$ $cm^3$ $sec^{-1}$, which produced the measured $H_2O^+$ ions. Referring to Figure 8, the $H_2O^+/O^+$ ratio is about 1% and is fairly constant with altitude, implying a relatively steady outgassing rate. The structural similarity between the $O^+$ and $H_2O^+$ distribution suggests that the $H_2O^+$ ions are produced near the vehicle. We now wish to determine exactly where the observed $H_2O^+$ ions are produced. We assume that the $H_2O$ molecules leave the surface suffering no collisions until at least several meters from the payload and that back-scattering is generally small. This means that the $H_2O$ molecules as well as the $H_2O^+$ ions are always moving away from the vehicle since there is typically no momentum transfer to the $H_2O^+$ ions in the reaction. Therefore, the measured $H_2O^+$ ions must be produced within the plasma sheath where the aperture plate potential can turn the ions around and draw them in. We further assume that the attractive potential is given by

$$V = 10\, e^{-\frac{x}{\lambda_d}} \text{ volts}$$

where x is the distance measured normal to the aperture plate and $\lambda_d$ is the Debye length. The Debye lengths for 200 km and above vary from 0.5 cm to 0.8 cm over the plasma density range of $1.5 - 4 \times 10^5$ cm$^{-3}$. The potential is sufficient to draw all the $H_2O^+$ ions into the spectrometer up to x = 2.7 cm and 4 cm, corresponding to the 0.5 cm and 0.8 cm Debye lengths, respectively. Note that these distances are essentially five Debye lengths so that the assumption of an exponentially decaying potential is not dramatically in error if it is accepted that by 10 $\lambda_d$ the sheath edge is definitely attained. The time, $\Delta t$, available for the reaction to produce $H_2O^+$ ions is then the time it takes $O^+$ to traverse the distance x and is calculated from

$$x = u_o \Delta t + 1/2\, a\, (\Delta t)^2$$

where

$$a = eE/m, \text{ and}$$

$$E = -\frac{\partial V}{\partial x} = \frac{10}{\lambda_d}\, e^{-\frac{x}{\lambda_d}}$$

and $u_o$ is the speed of $O^+$ in the x direction. The $O^+$ speed is determined from the vehicle motion and its thermal speed, from which $u_o \sim 10^5$ cm sec$^{-1}$. Varying $u_o$ from 0 to $2 \times 10^5$ cm sec$^{-1}$ changes $\Delta t$ by less than a factor of two. Calculating $\Delta t$ using the above values for x and $\lambda_d$, the average reaction time is found to be 17 $\mu$sec within 50%. The $H_2O$ concentration can then be determined from

$$\Delta [H_2O^+]/\Delta t = k\, [O^+]\, [H_2O],$$

since all $H_2O^+$ chemical loss processes are negligible in 17 $\mu$sec. With $\Delta[H_2O^+]/[O^+] = 0.01$ and $\Delta t = 17\ \mu$sec, $[H_2O] = 2.6 \times 10^{11}$ molecules cm$^{-3}$ to about a factor of two, which is the average concentration over the 4 cm distance from the surface. For T = 300K, (the surface temperature) this corresponds to a water vapor pressure of $8 \times 10^{-6}$ Torr, also to a factor of two uncertainty. This pressure range tends to support our collisionless assumption and is not atypical of observed laboratory outgassing pressures.

We plan in a future publication to examine past ionospheric rocket measurements to determine the spectrum of not only the $H_2O$ concentrations near rocket surfaces but also as a function of distance from the surface.

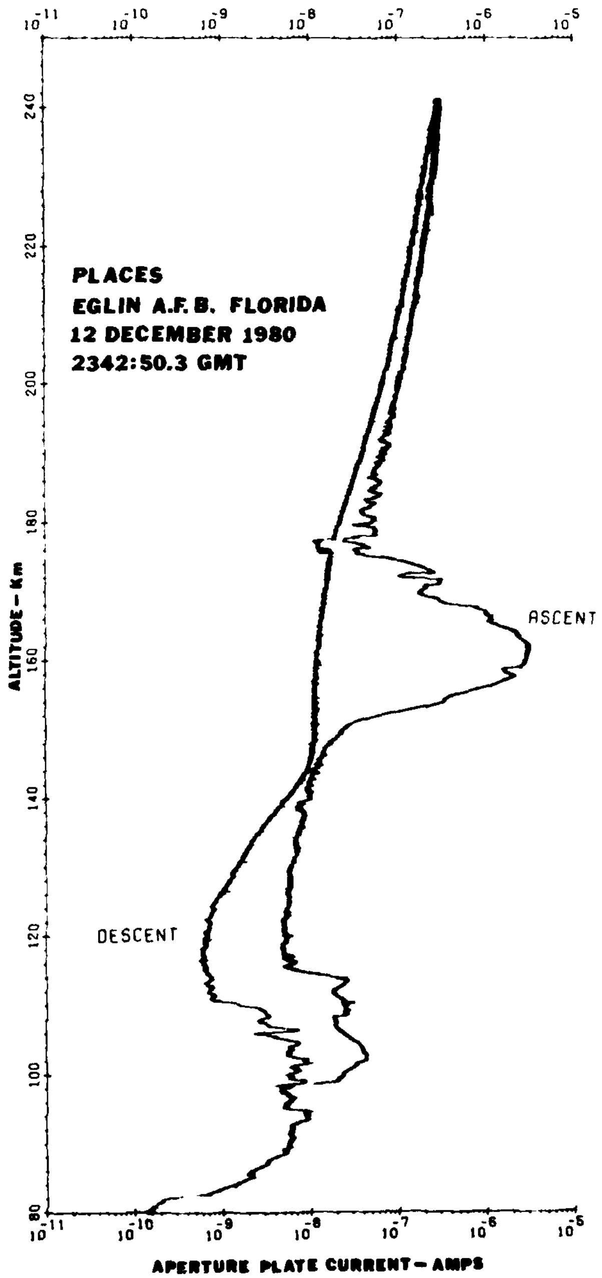


Figure 9. A Comparison of the Ascent and Descent Aperture Plate Current Measurements Showing the Smooth Ionosphere Adjacent to the Barium Cloud

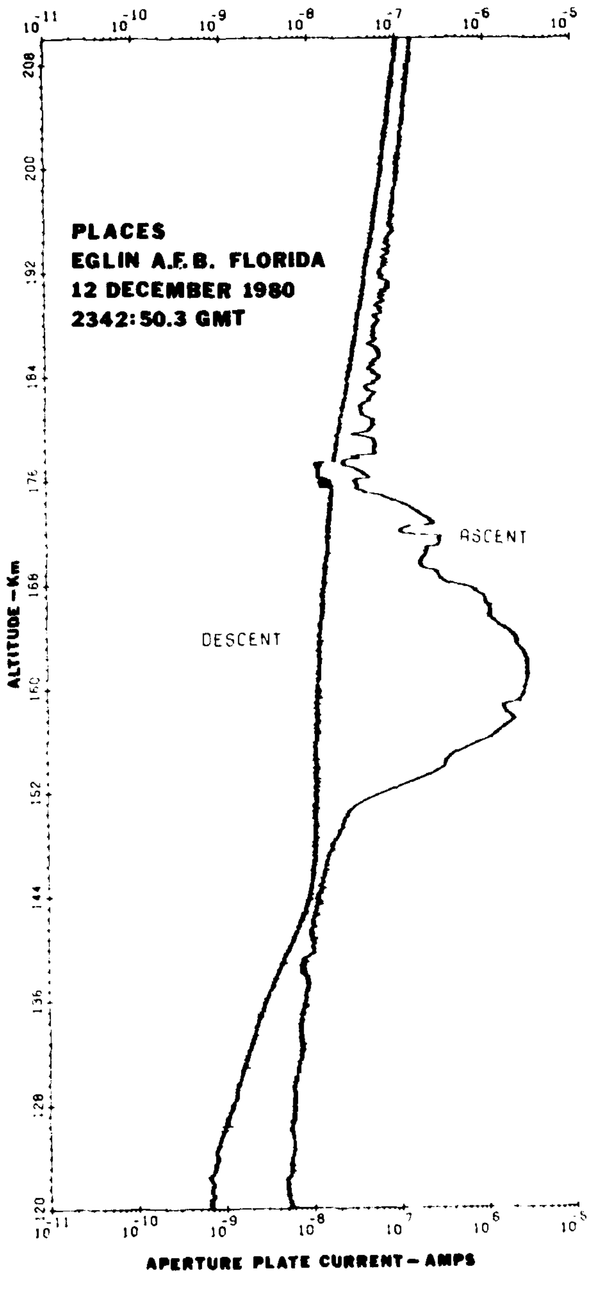


Figure 10. An Expanded Plot of the Ascent and Descent Aperture Plate Current Measurements in the Vicinity of the Barium Cloud

## 4. CONCLUSION

The first composition measurements in an ionospheric barium cloud have provided a wealth of information. Examination of the results led to the following observations:

(a) Several plasma chemical processes in the barium cloud were apparent from the ion species measurements, including the large recombinative loss of molecular ions, the $Ba^{++}$ chemistry, and the $Ca^{+}$ impurity ion chemistry.

(b) The microstructure of the plasma irregularities was accurately measured and further characterized by the species composition. Indeed the composition measurement provided the only way of determining that the density fluctuations above and below the barium cloud were not due to the barium ions.

(c) Mass dependent effects on the ion motions and instability development may be derived using the impurity tracer, $Ca^{+}$ (40 amu) and $Ba^{+}$ (138 amu) profiles.

(d) The first observation of an E region image cloud, which was visible only in the ion species distributions and not in the total density profile, have provided the initial measurements for a quantitative model assessment of these clouds.

(e) The wavelike structure in the natural ionospheric species extending into the F-region was unexpected and is currently not understood.

(f) A quantitative estimate of the outgassing water vapor concentrations near payload surfaces is provided for the first time utilizing the measured $H_2O^{+}$ ions. While outgassing contributed to only a 1% disturbance on the plasma measurements here, the perturbations on infrared and other rocket measurements may be more severe and these can now be assessed with increased accuracy.

## References


1. Baker, K.D., and Ulwick, J.C. (1978) Measurements of electron density structure in striated barium clouds, Geophys. Res. Lett. **5**:723.
2. Kelley, M.C., Baker, K.D., and Ulwick, J.C. (1979) Late time barium cloud striations and their possible relationship to equatorial Spread-F, J. Geophys. Res. **84**:1898.
3. Szuszczewicz, E.P., Holmes, J.C., Swinney, M., and Lin, C.S. (1981) DNA/PLACES barium event JAN: Quick-look field report on in-situ probe measurements, NRL Memorandum Report No. 4476.
4. Goldman, S.R., Ossakow, S.L., and Book, D.L. (1974) On the nonlinear motion of a small barium cloud in the ionosphere, J. Geophys. Res. **79**:1471.
5. Scannapieco, A.J., Ossakow, S.L., Book, D.L., McDonald, B.E., and Goldman, S.R. (1974) Conductivity ratio effects on the drift and deformation of F region barium clouds coupled to the E region ionosphere, J. Geophys. Res. **79**:2913.
6. Lloyd, K.H., and Haerendel, G. (1973) Numerical modeling of the drift and deformation of ionospheric plasma clouds and of their interaction with other layers of the ionosphere, J. Geophys. Res. **78**:7389.

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